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SOUTHWEST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE SOUTHWEST FISHERIES CENTER P.O. BOX 271 LA JOLLA, CA 92038

OCTOBER 1984

# PROCEEDINGS OF THE 35th ANNUAL TUNA CONFERENCE

by

Andrew E. Dizon

ADMINISTRATIVE REPORT LJ-84-35

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# PROCEEDINGS OF THE 35TH ANNUAL TUNA CONFERENCE

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P.O. Box 271
La Jolla, California 92038

OCTOBER 1984

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# PREFACE

The 35th Annual Tuna Conference was held once again at the University of California Conference Center, Lake Arrowhead, California, on May 21-23, 1984. The Conference, which was held for the first time in 1950, is an annual event and serves as a forum for exchange of information and ideas about tuna and tuna-like fishes. The meeting is now sponsored by the Inter-American Tropical Tuna Commission, La Jolla, California, and the National Marine Fisheries Service, La Jolla, California. In the past, the California Department of Fish and Game was also a sponsor.

Since the past year was the year of the El Niño, I thought it was appropriate for the Conference to emphasize the pelagic environment and the response of tunas and tuna-like fishes to it. Consequently, Session I of the meetings was devoted to the papers relating to the scombrid environment. Since, as always, presentations on tuna topics other than the primary theme are encouraged, Session II dealt with tuna fisheries and their analyses and Session III with tuna biology. Twenty-five papers were presented and 70 people attended the meeting representing a variety of institutions.

During the business meeting of the 34th Tuna Conference, a decision was made to collect a registration fee. So this year $700 was collected which will be used in the future to help with travel expenses for graduate students to attend the Conference.

The U.S. Tuna Foundation generously sponsored a sushi party for the participants on Monday evening; all the participants wish to thank them.

Several individuals deserve thanks for the help that they gave me in organizing the Conference. Many thanks go to Mrs. Frances Begley and Mrs. Pat Wilkins for their production of the documents for the conference. Thanks also to Ms. Jean Michalski for her help in editing the proceedings. Drs. Norman Bartoo, Michael Laurs, Gary Sakagawa and Elizabeth Vetter, NMFS, served as conveners of the four sessions. They exercised an unobtrusive authority over the sessions to ensure that the sessions were completed on time so that the other activities which have always been an important part of the tuna conference could take place. Dr. John Graves and Ms. Lisa Ankenbrandt helped me with the logistics of the Conference. Most important, I wish to thank Mr. Robert Olson, IATTC, the chairman of the 34th Tuna Conference, for all of the help and advice. Without his help, the organization of the Conference would have been very burdensome.

At the close of the Conference, by some mystic and ancient ritual, Mr. Kurt Schaefer was selected Chairman of the 36th Annual Tuna Conference.

Andrew E. Dizon

# AGENDA

Monday, May 21

0900 Welcome, Andrew Dizon, SWFC

## I. The Scombrid Environment

Convened by R. Michael Laurs

0915 "Eastern tropical Pacific Ocean temperatures during El Niño and some possible effects on tuna fisheries," presented by Forrest Miller, IATTC.

0945 "Environmental influences on tuna catches in the Gulf of Guinea," presented by Roy Mendelssohn, PEG.

1015 Coffee break.

1030 "Feeding habits of four species of Scombrids off southern California during summer 1983 -- an El Niño period," presented by Steve Reilly, SWFC.

1100 "Case study: Pelagics' migrations erratic and unpredictable during 1983-84-- Guam and Northern marianas," presented by Kenneth Larson, Western Pacific Fishery Management Council.

1130 "1983 sea surface temperature changes in relation to catch-temperature parameters observed for some pelagic species off Southern California," presented by James Squire, SWFC.

1200 Lunch.

1330 "Descriptive albacore-environmental studies at PEG: a progress report," presented by Paul Sund, PEG.

1400 "Progress in the tracking of fishery aggregation device-associated yellowfin tuna," presented by Kim Holland, University of Hawaii.

1430 "A possible mechanism for the association of pelagic fish with floating objects," presented by Richard Brock, University of Hawaii.

1500 Coffee break.

## II. Tuna Fisheries and their Analysis

Convened by Norm Bartoo

1530 "Yield per recruit analysis of sailfish in the western Atlantic Ocean," presented by Ray Conser, SEFC.

1600 "Cohort analysis without age information," presented by Pierre Kleiber, SWFC.

1630 "Méthode d' évaluation du stock de thonides de surface a partir des donnees de radiometrie et de prospection aerienne (Method of evaluating surface tuna stocks from radiometry and aerial survey data)," presented by Renaud Pianet, ORSTOM.

Tuesday, May 22

Tuna Fisheries and their Analysis (Cont'd)

0900 "Estimation of mortality, recruitment and fisheries interaction from analysis of tag returns," presented by John Sibert, South Pacific Commission.

0930 "Cost and earnings of U.S. troll vessels participating in the north Pacific albacore fishery," presented by Sam Herrick, SWFC.

1000 Coffee break.

## III. The Biology of the Scombrid

Convened by Elizabeth Vetter

1030 "Chromosome analysis of albacore, yellowfin and skipjack tunas," presented by Frank Ratty, San Diego State University.

1100 "Tetracycline validation of age estimates from Pacific bluefin tuna vertebrae," presented by Terry Foreman, IATTC.

1130 "Energetics and tuna movements," presented by Christopher Boggs, NMFS-NRC.

1200 Lunch.

1330 "An optimum pitching axis for the caudal fin motion of tuna," presented by George Yates, California Institute of Technology.

1400 "Aspects of blood chemistry in angling-stressed marlin," presented by Charles Daxboeck, Pacific Gamefish Foundation.

1430 "Thermal tolerance, and effect of temperature on the sustained swimming speeds of Scomber japonicus," presented by Kurt Schaefer, IATTC.

1500 Coffee break.

1530 "Scombrid systematics: current knowledge and problems," presented by Bruce Collette, Systematics Laboratory, NMFS.

1600 "Reproductive potential of swordfish in southern California waters," presented by Earl Weber, SWFC.

1630 "Morphological, metabolic and vascular characteristics of tuna heart ventricle: a review," presented by Bruno Tota, University of Naples.

Wednesday, May 23

## IV. Future Research

Convened by Gary Sakagawa

0900 "The NMFS strategic plan for albacore research and management," presented by R. Michael Laurs, SWFC.

0930 "Inter-specific relationships between eastern tropical Pacific tunas and their prey; implications for future research," presented by Robert Olson, IATTC.

1000 Coffee break.

1030 "Recent research efforts on Atlantic Tunas," presented by Peter Miyake, ICCAT.

1100 Business meeting.

### Poster

"Wind and albacore catch, 1970-77," presented by Paul Sund, PEG.

### Manuscript

"The relationship between fish migrations and yields in the western Pacific and El Niño eposides," presented by Hajinne Yamanaka, Far Seas Fisheries Research Laboratory, Shimizu, Japan.

### Newsletter

Tropical Ocean-Atmosphere Newsletter, May 1984, edited by David Halpern, JISAO, University of Washington.

# EASTERN TROPICAL PACIFIC OCEAN TEMPERATURES DURING EL NIÑO AND SOME POSSIBLE EFFECTS ON TUNA FISHERIES

by

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El Niño is only one manifestation of many adverse weather/ocean phenomena which occurs when the atmosphere and ocean circulations shift out of their usual patterns for a period of more than 6 months. To most scientists El Niño refers to a marked reduction in the easterly trade winds over the eastern north and south tropical Pacific, a marked rise in sea level and a deepening mixed layer along the west coast of North and South America, warm water invasion along coastal regions of South America and at the same time a marked decrease in upwelling and production of plankton. Torrential rains persist in the tropical convergence zone which an El Niño extends into the southern hemisphere over Ecuador and northern Peru. Also, ocean currents in the eastern tropical Pacific (ETP) undergo significant and abnormal changes in strengths and locations. For example, the California and Peru Currents often shift westward and weaken as an El Niño begins. Along the coasts of Baja California and Ecuador, weak countercurrents often surface and replace the displaced principal eastern boundary currents.

The 1982-83 El Niño began initially several hundred miles west of Peru in June 1982 as the southern winter approached. In August, when sea surface temperatures (SST's) normally approach minimum values, the ocean warming expanded rapidly along the equator east of 150°W and off the coast of South America from 5°N to 15°S. During the last two months of 1982 and the first quarter of 1983 the positive SST anomalies reach values as high as + 7°C in

equatorial areas centered around 130°W and along the coast of Peru. During the second quarter of 1983 (April-June) SST's remained 4° to 6°C above normal from the Galapagos Islands to the southern coast of Ecuador and along the coastal region of Peru. In July and August 1983 the very large anomalies, at the mid-point of the southern winter, remained 4° to 6°C above normal from southern Ecuador to Callao, Peru. During September gradual weakening of El Niño was revealed in the SST anomaly patterns. After October 1983 the positive anomalies were confined primarily to the tropical Pacific east of 110°W and from the equator to 20°S. Along the equator and west of 110°W, SST's were 1° to 2°C below normal indicating that equatorial upwelling was once again well established in the central part of the tropics.

The distribution of yellowfin and skipjack tunas in the eastern tropical Pacific and their vulnerability to capture by purse seining may be markedly affected by a major environmental event such as El Niño, especially if the ocean event is widespread and prolonged. It is apparent that there are no clearly defined patterns in the annual catches of yellowfin and skipjack which can be directly linked with oceanic and atmospheric conditions during El Niño years. However catches of both yellowfin and skipjack during 1957/1958 and 1982/1983 were below average and this might have been related to El Niño extending over a two-year period. It is difficult to evaluate precisely whether these poorer than average catches in 1957/1958 and 1982/1983 were artifacts of the trends in catch or were a result of environmental conditions reducing the availability and/or vulnerability of the fish. It is possible to detect gross relationships between El Niño conditions and catches of tropical tunas when annual data are examined. However, to more clearly examine these relationships will require that both fishery and environmental data be analyzed on a much finer scale in both time and space.

# ENVIRONMENTAL INFLUENCES ON THE F.I.S.M. TUNA CATCHES IN THE GULF OF GUINEA

by

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Using the F.I.S.M. (France, Ivory Coast, Senegal, Morocco) catch data and atmospheric and oceanographic data from 1969 to 1979, we have divided the Gulf of Guinea into eleven areas which are related to a typical catch or environmental process. Within each subarea, we have fortnightly Catch Per Unit Effort (CPUE) data of purse seine fishing for yellowfin and skipjack tuna, as well as fortnightly means of sea surface temperature (SST) and the east and north components of wind velocity; however, there are missing data points in these series.

Using a recently developed algorithm, we estimate local models that "complete" the five series in each of the eleven areas. Evidence is given that the model estimates for the missing data points are reasonable, and that the missing CPUE data are estimated almost entirely from the environmental data. Further examination of the local models suggests that the environmental variables are acting as surrogates for an oceanographic process that causes favorable fishing conditions. This process involves upwelling and concentrations of nutrients a month before the period of fishing, followed by

relatively warmer waters two weeks before the period of fishing.

Spectral density matrices were then calculated for the fifty-five "completed" data series. From these we calculated the dominant modes of variability of each parameter in time and space by frequency, and also the dominant modes of variability between parameters in time and space by frequency. The dominant mode for SST shows a space-time movement that is consistent with a recently developed theory of remote forcing in the equatorial Atlantic. The dominant modes for CPUE for both yellowfin and skipjack tuna show relatively little discernible pattern.

However, when the dominant modes are calculated between SST and CPUE for yellowfin and skipjack tuna, SST displays the same space-time pattern of coastally trapped propagation as it did when examined alone while the CPUE data now exhibit the same movement in space and time as SST and at about the same speed. These results suggest that the predictability of CPUE in the local models is in large part due to a broad scale oceanographic process which may be associated with remote forcing in that region.

# FOOD HABITS OF THREE SPECIES OF TROLL-CAUGHT SCOMBRIDAE OFF SOUTHERN CALIFORNIA DURING SUMMER 1983: A PROGRESS REPORT

by

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We investigated the food habits of three species of scombrids collected during Cruise 166 of the NOAA research vessel David Starr Jordan in August 1983 to examine possible effects of the El Niño phenomenan of that period. Chi-square analysis for homogeneity showed highly significant differences in types of prey and proportions consumed by the three scombrids. Albacore (Thunnus alalunga) consumed 96.8% fish, 35.1% cephalopods, and 51.2% crustaceans by frequency of occurrence, and 82.4% fish, 1.7% cephalopods, and 15.9% crustaceans by numerical frequency. Skipjack tuna Katsuwonus pelamis) consumed 19.4% fish, 12.9% cephalopods, and 54.8% crustaceans (45.2% euphausids) by frequency of occurrence, and 11.1% fish, 2.6% cephalopods, and 86.3% crustaceans (76.5% euphausids) by numerical frequency. Bonito (Sarda chiliensis) consumed 71.4% fish, and 26.2% crustaceans (11.9% euphausids) by frequency of occurrence, and 32.1% fish, and 67.9% crustaceans (63.4% euphausids) by numerical frequency. A total of 94 albacore , 31 skipjack, and 42 bonito stomachs were examined. A comparison to historical data during similar and dissimilar environmental conditions showed that the scombrids are opportunistic predators, and that prey availability was partly a function of the oceanographic conditions. Determination of the percent volume and calculation of the Index of Relative Importance (Pinkas et al. 1971) of prey items for the three predators are in progress.

# 1983 SEA SURFACE TEMPERATURE CHANGES IN RELATION TO CATCH-TEMPERATURE PARAMETERS OBSERVED FOR SOME PELAGIC SPECIES OFF SOUTHERN CALIFORNIA

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The period of warmer than normal sea surface temperatures during the El Niño years of 1982 and 1983 resulted in some unusual migrations of tropical and sub-tropical fishes and invertebrates into northern latitudes. Catch-temperature parameters for several pelagic species observed off southern California were compared with the sea surface temperature environment observed in the northern latitudes. Catch-temperature parameters observed off southern California for species of yellowtail (Seriola lalandia), Pacific barracuda (Sphyraena argentea), Pacific bonito (Sarda chilensis), chub (or Pacific) mackerel (Scomber japonicus), white sea bass (Cynosion nobilis), striped marlin (Tetrapturus audax) and yellowfin tuna (Thunnus albacares) were used in the analysis.

Observations of sea surface temperatures in the northern latitudes of the northeast Pacific during the summer and early fall of 1983 would indicate that the low monthly mean catch temperatures at which the sub-tropical pelagic species were caught off southern California (excluding yellowfin tuna and striped marlin) were commonly observed off southeastern Alaska and in the northern Gulf of Alaska.

# GUAM'S EL NIÑO - PELAGIC MIGRATIONS WERE UNPREDICTABLE AND ERRATIC DURING THE 1983-84 SEASON

by

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Mahimahi (Coryphaena hippurus) are temperature sensitive fish preferring approximately 24°C. Seasonal reduction in the sea surface temperature in autumn triggers an annual migration into the Guam fishery. November had signaled the beginning of the mahimahi migration for the preceding three years with a peak in the harvest occurring in March of each season. Shortly after mid-April harvests fall off dramatically.

In 1983, however, catches of mahimahi started in mid-October--a month early. Expectations among the fishermen and dealers were for a bumper year and preparations were made for increased refrigeration capacity and supplies of shipping boxes. But the catch declined starting in early November, and by December, mahimahi was rarely landed. The slow harvest continued until mid-January when more and larger fish started appearing in the catch. The harvest rate increased rapidly until the end of February, but collapsed by the end of March. Higher than normal temperatures were observed through the winter season (no winter decrease at all), suggesting that the temperature-sensitive mahimahi altered their migration patterns, which resulted in the failure of the harvest around Guam.

# DESCRIPTIVE ALBACORE-ENVIRONMENTAL STUDIES AT THE PACIFIC ENVIRONMENTAL GROUP - A PROGRESS REPORT

by

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Research at the Pacific Environmental Group (PEG) focuses on time-series analyses of fisheries and environmental data. Comparisons are made between environmental factors, fish distributions and fish abundance. We recently have begun albacore-environmental studies, the fishery data base for which is a computer tape of logbook reports for the period 1961-1981. The data include date and location of catch, numbers of fish caught and some environmental data. We intend to study the time variability of the fishery in relation to changes in the environment. In preparation for these studies, a series of maps was prepared which provides a descriptive history of the catch distribution and abundance for the period. Because we feel it is of general interest, some historical aspects of the fishery revealed by the maps are presented. Three sets of charts were prepared: (1) monthly total catch for each month for the years 1961 to 1981, (2) average monthly catch, and (3) annual total catch for each year from 1961 to 1981.

## Growth of the fishing season

These data show a persistent expansion in duration of the fishing season since 1972. In the 1960's and early 1970's the fishery occurred principally from June to October, but by 1977 and 1978 fishing had expanded to all months but February and March. The 1981 season was the longest recorded for the

years studied.

## Expansion westward

Exploration offshore of the traditional southern California coastal grounds was first evident in 1972 and 1973. In 1975 the "Midway" area was first explored, and that fishery began in earnest in 1980. The Midway fishing season occurs from April to July. A second new offshore area was opened in 1980 and 1981 about 800 to 1000 miles west of Oregon and southern Washington. Activity there peaks in August and September.

## Catch distribution

Earliest catches in recent seasons were made in the Midway area in April/May. As the season progressed the catch locations moved both north and east towards the Washington coast. (Such a distribution is reminiscent of the seasonal shift in the Subarctic Convergence; this association of catch [fish] distribution and oceanographic feature will be investigated.)

In the coastal region, two centers of abundance appear in June and July, one north and one south of roughly 40°N. Certain years have been termed "North" or "South" seasons because a predominance of the coastal catch has been either north or south. Tabulations and plots of catch and landings data showed that for most years between 1947 and 1975 the catch distributions alternated between the north and south areas. That is, high catches in southern waters coincided with low catches in the north and vice versa. Prior to 1947 the catch in the two regions tended to rise together, and after 1976 a general decline in catch occurred in both regions. That the latter decline is environmentally related has been proposed.

Four centers of apparent abundance are evident: southern California

inshore, Pacific Northwest and northern California inshore, Northwest offshore, Midway. We will compare the distribution and abundance of the fish in these areas with numerous environmental variables, collected both at the surface and at depths at which albacore characteristically swim.

# PROGRESS REPORT ON ULTRASONIC TRACKING OF FAD-ASSOCIATED YELLOWFIN TUNA

by
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We are at the midway point in a cooperative NMFS/University of Hawaii/ Sea Grant project designed to track the horizontal and vertical movements of 50-70 cm yellowfin and bigeye tuna found in association with fish aggregation devices (FADs). Although much of the past year has been involved with improving the tracking vessel and equipment, we already have five tracks. The longest track spanned 6 days. A major innovation has been a hydrophone faring which permits data acquisition and tracking at speeds of over 7 knots.

All the tracks so far completed show diurnal and other, shorter period rhythmicities in both horizontal and vertical swimming behaviors. We have tracked two FAD-associated bigeye tuna and their daytime depths are much deeper than those of the yellowfin. Both species swim much closer to the surface at night. Both of the bigeye tracks display remarkably regular upward excursions which occur about once an hour.

Preliminary indications are that the effective range of a FAD is 6 to 10 miles. One animal swam in a direct course from one FAD to another FAD located 9 miles away. Comprehensive analysis of the vertical and horizontal behavior and relationships among movement and current and temperature data has not yet begun. We hope to expand the project to include other target species and different size classes.

# A POSSIBLE MECHANISM FOR THE ASSOCIATION OF PELAGIC FISH WITH FLOATING OBJECTS

by
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A model and data are presented suggesting that the association of pelagic fish with floating materials occurs in a predictable sequence. Smaller prey fishes rapidly recruit to the object using it as a source of shelter from predation. This recruitment is relatively continuous and linear over time. The first arriving predators to the object (within 1 to 8 days) associate with it to take advantage of accumulated prey. Predators rapidly decrease prey abundance . At lower prey densities, predators use the floating object as a focal point in their search for prey. The drifting object moves in one direction in a current system (or in the case of a moored object the water flows by), thus object-associated predators eliminate the searching of previously explored water and hence are more effective. Due to their normal migratory nature, predators eventually leave the object to be later replaced by others.

# YIELD PER RECRUIT ANALYSIS OF SAILFISH IN THE WESTERN ATLANTIC OCEAN

by

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Sailfish (Istiophorus platypterus) are distributed throughout the Atlantic Ocean, from 30° S to 30° N latitude. They have pronounced seasonal variations in abundance and distribution over most of their range. Catch rates indicate that the densest concentrations occur in the western Atlantic, near coastal areas. Abundance in the eastern Atlantic is generally lower, although localized areas of high concentration have been reported off the western coast of Africa. Stock structure is uncertain; the most commonly used working hypothesis is that there are two stocks, one in the western Atlantic and another in the eastern Atlantic. Sailfish are exploited by recreational fishermen in coastal areas on both sides of the Atlantic and by the high seas longline fisheries throughout their range.

Historically, stock assessment work on sailfish has been hampered by shortcomings of the data reported on landings from the longline and recreational fisheries and by difficulties in ageing the fish. Catch and effort statistics for the longline fisheries, which have been quite useful for assessment work on tunas and other billfishes, have been of limited value for sailfish, since the catches of sailfish and spearfish have been combined in the reported statistics. Monitoring of the status of stocks has been limited to following CPUE and average size trends from the U.S. recreational fishery and surplus production model analyses using catch estimates from the various

nations taking sailfish throughout the Atlantic. The latter approach has required assumptions that have been tenuous, especially those concerning the aggregation of sailfish and spearfish catches in the longline records.

Two recent publications have improved the stock assessment situation for sailfish. Kikawa and Honma (1983 ICATT Coll. Vol. Sci. Pap. 18(3):645-649) have published data from the Japanese longline research cruises in the 1960's and early 1970's, in which the catches of sailfish and spearfish were recorded separately. These data have been useful for partitioning the aggregated catches and estimating the sailfish landings (1984. Proc. Int. Workshop on Age Determination. NOAA Tech. Rpt). Hedgepeth and Jolley (1984) have published the results of their age and growth work on sailfish using dorsal fin spines. Their samples were obtained from the U.S. recreational fishery in the western Atlantic. It is now possible to do a more comprehensive study of sailfish population dynamics and to examine the response of the western Atlantic stock to fishing pressure. As a first step, yield per recruit (Y/R) analysis was conducted on the western Atlantic stock.

Y/R analysis was conducted under a variety of assumptions concerning sailfish growth and mortality rates. The appropriateness of various growth models was investigated. Mortality rates were estimated and compared with those presently in the literature. The effect of sexually dimorphic growth was also considered. Sensitivity analysis was carried out to investigate the effect of various ages at entry, natural mortality rates, and assumptions concerning ageing.

Using the best estimates of growth and mortality parameters, the Y/R curve is flat-topped such that maximum Y/R will not be attained for any practical fishing mortality rate. $F_{0.1}$ (where the slope of the Y/R curve is one tenth of the slope at the origin) occurs at F=0.55 per yr. The range of

estimates of F from the literature is quite wide (0.18 to 1.01) but the best estimate is F=0.34 with standard error 0.02. Fishing mortality is, therefore, likely to be below the $F_{0.1}$ level. The rapid growth of sailfish and the relatively late age at which they are fully recruited to the fishery (age 4) produces a healthy situation by the Y/R criterion. Sensitivity analysis indicates that these conclusions are robust to most of the parturbations explored, with the exception of younger age at entry (age 1), slower growth (true age two yrs older than expected), and lower natural mortality (M=0.15). If M is lower than M=0.34 (best estimate) or if growth is slower and the age at entry should decline, then there may be some concern about the condition of the stocks. Otherwise, western Atlantic sailfish appear to be only moderately exploited when viewed from the Y/R perspective.

Future work will include surplus production model analysis, cohort analysis, and simulation modeling of western Atlantic sailfish in order to better understand their population dynamics.

# COHORT ANALYSIS WITH IMPRECISE AGE INFORMATION

by

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Two approaches to the problem of estimating recruitment and fishing mortality were discussed for the situation where the age-length function is an average growth pattern to which the individuals in the population do not precisely conform.

One approach is to estimate the age composition in the catch using new methods that correct for the bias inherent in the use of an average age-length function. With knowledge of the correct age composition, traditional cohort analysis can be carried out for the estimation of recruitment and fishing mortality.

The other approach is to use length structured cohort analysis. A formulation was presented of an analytical model for an improved length structured cohort analysis. This model should allow one to estimate a time series or recruitment values and a series of length-specific catchability coefficients. The latter could be used to calculate fishing mortality. Effort statistics and catch statistics with length composition are required. A method to fit this analytical model is currently under development.

An individual fish model was discussed. This model keeps track of the length and age of each individual in a population of fish with individually variable growth parameters. Any desired pattern of recruitment and fishing effort can be specified. The exact age and length compositions of fish in the catch and at large can be determined at any time. This model was developed for the purpose of testing both of the above approaches to estimating recruitment and fishing mortality.

# AERIAL RADIOMETRY AND TUNA SURVEY: A METHOD FOR EVALUATION OF SURFACE TUNA STOCKS IN NEW CALEDONIA - VANUATU AREA

by

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## ABSTRACT

From February 1979 to December 1982, 1,452 hours of aerial radiometry and tuna survey were conducted in the New Caledonia - Vanuatu area. The results of these surveys are analyzed in relation to the hydroclimatic and fishing environment.

Data are presented, and the proposed mathematical model (using non-parametric statistics) attempts to take into account the influence of the different parameters (time, sea surface temperature, clouds, sea state, distance from land, distance between schools, season, etc.) as well as the discontinuous character of the sightings (tuna schools, birds, whales and porpoise, etc.). The concept of mathematical distance $\delta$, which allows the data to be reduced to a single dimension, is used. By fitting a curve to these data, we can compute the relationship between $\delta$ and the spot probability (VP: visible potential) which is used as an index of abundance. Then, using an estimate of the school size and area surveyed, we can also compute the relationship between $\delta$ and the tuna density. We found that the two functions are exponential. Finally, using this estimated density, the surface tuna potential of the New Caledonia - Vanuatu area was evaluated.

# ESTIMATION OF MORTALITY, RECRUITMENT AND FISHERY INTERACTION BY ANALYSIS OF TAG RETURN DATA

by

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Simple models of tag attrition used for analysis of tag and recapture experiments as applied to single fisheries for skipjack tuna are reviewed. The problems of separating attrition into components due to natural mortality and migration are discussed. A model of tag attrition in two fisheries is presented which explicitly includes migration terms. These terms enable the separation of mortality from emigration and the calculation of interaction between fisheries. The model is fitted to an example data set derived from tagging of skipjack tuna in two pole-and-line fisheries in the western Pacific Ocean. It is concluded that models of tag attrition and exchange can be used to obtain reasonable estimates of population parameters. For the example data set, it would appear that migration is a minor component of attrition.

A second model is introduced for the mixing of tuna around an island or other large attractant. This model is a preliminary attempt to express the potential for interaction between an island-based artisanal fishery and a large industrial fishery. The principal parameters are mortality and dispersion, both estimated from skipjack tagging. Preliminary results suggest that industrial fisheries operating within 100 miles of an artisanal fishery may potentially have a substantial impact.

# COST AND EARNINGS OF U.S. TROLL VESSELS PARTICIPATING IN THE NORTH PACIFIC ALBACORE FISHERY

by
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Cost and earnings data and catch and effort data were provided by 57 vessels participating in the north Pacific albacore fishery for the years 1976 to 1982. Initially these data were used to estimate catch rate and cost equations that relate catch and cost elements to the vessel's physical characteristics. Hold capacity was found to be the most significant physical characteristic in terms of explaining a vessel's daily catch rate and fuel consumption. The catch rate and fuel consumption relations were then used to predict the vessel's respective gross revenue and fuel cost for an albacore fishing trip of a specified length. Galley, gear and labor costs were also estimated for the trip under consideration. These revenue and cost elements were all combined in an electronic spread sheet which was based on a net cash flow model for an albacore fishing trip. For a particular vessel, described by its physical characteristics, the model predicts the net cash flow for a trip of given length. Results from the model were then used to derive cost functions that relate the cost per ton of albacore caught to the level of catch. The cost functions were in turn used to conduct a break-even analysis which determines the level of albacore catch necessary for a vessel to just cover its fishing trip costs. For 1982, the break-even catch for vessels greater than 40 tons hold capacity was approximately 45 tons; for vessels of 40 tons capacity or less the break-even tonnage was approximately 5 tons. Catches greater than these respective amounts would result in a positive contribution to the vessel's fixed costs of fishing.

# CHROMOSOMAL ANALYSIS OF ALBACORE, YELLOWFIN AND SKIPJACK TUNA

by

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Chromosomal analysis is being used as part of an investigation of the population structure of the North Pacific albacore, Thunnus alalunga. Results from recent tagging studies suggest that northern and southern substocks constitute the North Pacific albacore population and that these proposed substocks have different migratory patterns. In this report, we present the chromosomal analysis for albacore from the proposed North Pacific southern substock and compare them with similar results we obtained for yellowfin tuna (Thunnus albacares) and skipjack tuna (Katsuwonus pelamis). All blood samples were collected from freshly caught fish aboard the NOAA Ship David Starr Jordan (August 1983) or aboard fishing boats (October-November 1983). Lymphocytes were separated on a density gradient of ficoll and sodium distrizoate to obtain an erythrocyte-free culture having a higher mitotic index. Cells were harvested, slides prepared and chromosomes C-banded according to modified mammalian procedures. It was demonstrated that the diploid numbers of the albacore, yellowfin, and skipjack were 2N-48. We found that chromosome morphology of the albacore compared more closely with that of

the yellowfin tuna than the skipjack tuna. The albacore and yellowfin tuna have three pairs of biarmed chromosomes and twenty-one pairs of uniarmed chromosomes while all of the skipjack tuna chromosomes are uniarmed. C-banding was done to differentiate individual chromosomes on the basis of centromeric, terminal and intercalary bands. The three species could be characterized by their banding patterns. Our results demonstrate that there is a genetic basis for placing the albacore and yellowfin tuna in the genus Thunnus and the skipjack tuna in the genus Katsuwonus on the assumption that more closely related species will share certain karyotypic characteristics. Hypotheses for the chromosomal mechanisms that might have resulted in the observed differences in chromosome morphology and C-banding patterns are presented. Although C-banding techniques did not allow a detailed evaluation of the Thunnus chromosomes, we believe that G-banding procedures will be an important next step in determining if genetic heterogeneity exists in the North Pacific albacore population.

# TETRACYCLINE VALIDATION OF AGE ESTIMATES FROM PACIFIC BLUEFIN TUNA VERTEBRAE

by

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The study on age and growth of bluefin tuna in the north Pacific implemented in 1980 by the IATTC has continued with analysis of the oxytetracycline (OTC)-marked vertebrae collected from a tagging experiment initiated in 1981. Tagging results indicate a fast growth (6-8 cm/mo) for young-of-the-year (20-25 cm) bluefin marked in the summer and recaptured by December, followed by slower growth in the winter (1.5 cm/mo). Three of the OTC returns recaptured during April-July 1982 were recovered in the western Pacific (4 cm/mo) and one in the eastern Pacific (3.1 cm/mo).

The results of the vertebrae analysis show a linear relationship between vertebral radius and fish fork length, described by the equation FL = 0.825 + 6.70 R, where FL = fork length (cm), R = vertebral radius, and $r^2 = 0.987$. Because of the linear relationship, the length at annulus formation appears best calculated from the simple equation

$$S_{ann} = \frac{r_1}{r_2} \cdot \Delta FL$$

where $S_{ann}$ = fork length at annulus formation, $r_1$ = vertebral radius (mm) from OTC mark to the annulus, $r_2$ = vertebral radius from the OTC mark to the edge,

and $\Delta$ FL is the growth in fork length (cm) from mark to recapture. The distinct advantage of OTC marking in validation of annual marks is the ability to backcalculate the time of annulus formation, which was accomplished by direct interpolation from the equation

$$T_{ann} = \frac{r_1}{r_2} \cdot DL$$

where $T_{ann}$ = time after tagging of annulus formation in days, and DL = days at liberty. The results of calculations show the annulus formed between February and May (mean - April 12) at 50 cm fork length. Backcalculation of size at annulus formation from data taken from the eastern Pacific catch (non-tagged or injected) displays similar results ($\bar{X}$ = 49 cm).

This study estimates size-at-annulus-formation to be slightly smaller than previous studies, especially for ages 1-3, although this trend is overcome by age 6.

Future research will center upon derivation and comparison of growth curves from both otolith and vertebra. Time of annulus formation will be further examined through analysis of tag return data.

# ENERGETICS AND TUNA MOVEMENTS

by

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Fast sustained swimming and high costs of locomotion probably affect the directed movements, rates of mixing, and mortality rates of tuna populations. The apparent inefficiency of locomotion in tunas compared with other fishes can be explained as a byproduct of their design for higher performance (sustained speed) than other fishes. A model that illustrates the risks and benefits of swimming faster than "optimal" foraging speeds in environments where food is patchily distributed over great distances can help explain the adaption for fast sustained speeds in tunas. This model postulates that tunas are "energy speculators" that deviate from the most prudent energy-efficient strategy to maximize the rate of growth and reproduction. A consequence of this strategy may be an increased mortality rate among less successful individuals.

The optimal foraging speed can be modeled using information on locomotory costs determined in experiments with live tuna at the Kewalo Research Facility in Honolulu. Optimal foraging speed increases with food density to an asymptote at very high densities. Different optima may be defined. For any food density there is a speed where there is the greatest energy intake per unit energy expended and a speed with the greatest net energy intake per unit time. In a prudent predator, speed should be dependent on the ambient food density. By swimming slowly when food is scarce, the predator minimizes

energy losses and maximizes efficiency under the ambient conditions. There is little risk, a speculative predator would speed up incurring net losses of energy to increase the frequency of encounter with patches of food. If a patch is rich it can more than compensate for the extra cost. The risk each speculative predator faces is that it may not find such a patch. The net energy lost through locomotory costs could result in starvation or as reduced performance resulting in mortality.

The loss of average whole body energy content that results in mortality has been experimentally determined to be in excess of 50% in 3 species of tuna at Kewalo Basin. This can be used to predict a "point of no return" in energy speculation for different speeds and food densities. Yellowfin tuna (45 cm fork length) should be able to swim 1270 km at 1 knot or 641 km at 6 knots without any food. At a food density required to maintain metabolic costs while swimming at minimum speed (1 knot) a yellowfin could swim 1302 km at 6 knots or 3170 km at 3 knots before dying of starvation.

Speed is the easiest component of tuna movement to estimate and measure. Direction and the rate of change of direction must also be understood. Direction probably has a high rate of change when food is abundant since this would keep tuna within a patch. As food abundance declines the rate of change of direction probably declines as tuna search for more productive areas. Thus, on a large scale tuna may appear to travel the least when they are actually swimming fastest and changing direction frequently. Tuna probably make the largest movements when food is scarce or when they anticipate desirable resources or conditions at a distance.

# THUNNIFORM LOCOMOTION:
# An Optimum Pitching Axis for the Caudal Fin

by

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The Thunniform mode of propulsion is characterized by a stiff caudal fin mounted posterior to a very narrow and relatively inflexible peduncle. An elaborate arrangement of muscles, tendons, and bones permit effective control of the angle of inclination of the caudal fin during the swimming cycle. This study was undertaken to understand some of the constraints imposed on the fish physiology, energetics, and anatomy by the external fluid forces. Both the energetics of force and moment production and the need for effective maneuverability are considered. In this way, a doubly optimum solution is obtained.

The time dependent forces and moments acting on the caudal fin can be estimated using two-dimensional unsteady aerodynamic theories. These theories are used to find an optimum tail motion which minimizes the energy lost in the wake while maintaining a constant forward thrust. This motion is then compared with observed caudal fin movements. Both the observed and predicted motions are further analyzed to find an optimum pitching axis about which the root mean square moment and power to produce moment are minimum. This new axis is located on the fin approximately one quarter of the distance from the fin's anterior edge to its posterior edge. It is further forward than previous investigators have contended, and depends on the tail beat frequency and the wing loading. This choice of pitching axis may enhance performance and control of rapid maneuvers and thus enabling the fish to more adeptly avoid predators or capture prey. In tuna the muscle groups responsible for

controlling pitch and those for producing heave are not easily distinguished and the location of the pitching axis remains to be clearly identified. Observations and measurements aimed at isolating the moment and the constituent parts of the power (for thrust and for moment) are needed to help clarify the position of the pitching axis.

# ASPECTS OF MARLIN EXERCISE IN PACIFIC BLUE MARLIN, *Makaira nigricans*, OF HAWAII

by

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Preliminary findings from experiments performed at the Pacific Gamefish Foundation laboratory during August 1983 will be discussed. These findings are summarized briefly below. All samples were obtained from Pacific blue marlin, *M. nigricans*, as soon as possible after capture. These fish were caught on hook and line by participants of the Hawaii International Billfish Association billfish angling tournaments.

1. Blood oxygen dissociation curves display very large Bohr shifts to the

right when subjected to metabolic or respiratory acidotic conditions.

2. Marlin blood displays a very pronounced Haldane effect with increased levels of $CO_2$ which accompanies exercise.

3. There is a large Root effect upon the oxygen dissociation curve of marlin blood (pH range 7.0 to 8.0).

4. The oxygen binding curve of "normal" marlin blood appears unaffected by temperature changes over the range of 15° to 25° C.

5. Marlin blood has an enormous non-bicarbonate buffering capacity of - $\beta$ = 26.5 slykes at an hematocrit (Hct) = 50%, [Hb] = 14 g%, plasma, - $\beta$ = 4.0 slykes.

6. Colloid osmotic pressure of marlin plasma decreases as a function of fight time. There are no correlations between fight time and Hct, despite the fact that the spleen weight decreases with the duration of the angling.

7. Blood lactate levels increase linearly with fight time, and after 60 minutes reach levels of 36 mM.

8. Marlin white muscle has a high anaerobic capacity for maintenance of contraction and appears to be temperature independent for performance over a range from 15° to 25°C.

9. The coronary vasculature of marlin contains alpha-constrictor and beta-

dilator adrenoceptors.

The significance of these findings on the adaptive capacity of Pacific blue marlin for superb exercise performance and for recovery from severe physiological stress following angling will be illustrated.

temperature, using dummy variables for temperature categories, was fit to the data after correcting for autocorrelation. The observed lowest and highest non-stressful temperatures are suggested to have the greatest ecological significance for predicting the distribution by temperature of S. japonicus.

# STATUS OF THE SYSTEMATICS OF THE SCOMBROIDEI

by

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The Scombroidei is a suborder of the Perciformes and is composed of six families, 44 genera, and nearly 100 species. Six families are recognized: Scombrolabracidae (monotypic); Gempylidae (15 genera, 16 species); Trichiuridae (9 genera, at least 20 species); Xiphiidae (monotypic); Istiophoridae (3 genera, about 11 species) and Scombridae (15 genera, 49 species).

Some taxonomic problems remain in most of the scombroid families. There are two generic problems in the Gempylidae (whether Tongaichthys and Thyrisitops are distinct, is Paradiplospinus a synonym of Diplospinus) and one species problem (are there one or two species of Ruvettus). Species of the two most speciose genera of Trichiuridae (Benthodesmus and Aphanopus) are not well defined. Atlantic and Indo-Pacific populations of blue marlin (Makaira nigricans) and sailfish (Istiophorus platypterus) differ but it is not clear whether the differences are specific or subspecific. Most species of Scombridae seem well-defined but there are problems in the systematic placement of Gasterochisma and Grammatorcynus. The only species problem is with the frigate tunas (Auxis). The two Indo-Pacific species are well defined but the status of the Atlantic species is not yet clear: are there one or two species, and are they the same as in the Indo-Pacific?

# THE SEX RATIO AND GONAD INDICES OF SWORDFISH (Xiphias gladius) CAUGHT OFF THE COAST OF SOUTHERN CALIFORNIA IN 1978

by

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The gonads of 90 swordfish, (Xiphias gladius), captured off the west coast of the U.S., were analyzed to determine their reproductive condition. All swordfish were mature and a sex ratio of 0.34:1 (M:F) was observed. The proportion of females captured each month varied. Gonad indices and a histological analysis indicated the swordfish were not reproductively active and showed no evidence of recent spawning activity.

# MORPHOLOGICAL, VASCULAR AND METABOLIC CHARACTERISTICS OF THE VENTRICULAR MYOCARDIUM OF ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS* L.)

by

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Compared with the hearts of most fishes, the ventricular myocardium of tunas shows a high level of structural and vascular organization.

The relative heart weight in tunas with body weights ranging from 0.6-350 kg is greater than in other marine fish and corresponds to values found in small mammals. The relative heart weight exhibits two different growth velocities, with the breaking point between 10 and 20 kg of body weight.

The concentration of cardiac myoglobin is very high when compared with that of other fishes, and also shows two distinct size-concentration relationships, smaller tunas having lower values compared with the larger ones. The breaking point is close to that of the body weight to heart weight relation (Poupa, O., et al. 1981 *Comp. Biochem. Physiol* 70A: 217-222).

By using histological methods combined with vascular cast techniques and india ink injections, a tentative classification of the functional myocardial organization in fishes is presented. On this basis, it becomes evident that the myoarchitectural and vascular design of the ventricular myocardium of the tunas reaches one of the highest levels of cardiac organization which has been reported in fishes. Both the histological texture of the outer compact layer (compacta) and its coronary vascular pattern show remarkable homology with the arrangement of the homeotherm subepicardial musculature. On the other hand,

the inner core of the ventricular muscle (spongiosa), which is mostly supplied by the venous blood from the ventricular lumen, shows also a complex arborization of coronary arterioles and capillaries with extensive arterio luminal anastomoses (Thebesian system, Tota, B., et al. 1983 Am. J, Anat. 167: 15-32).

The different microenvironments of the compacta and the spongiosa as well as the different performance of these two compartments are considered and related to their metabolic heterogeneity. Aspects of such heterogeneity are the different capacities of these two layers to both carry out different stages of lactate oxidation and to incorporate lactate into the total cardiac lipids. This heterogeneity is also reflected in the specialization of the mitochondrial populations from the compacta and the spongiosa (Tota, B. 1983. Comp. Biochem Physiol. 76A: 423-437).

The morphometric, structural, vascular and metabolic cardiac characteristics of the tunas are related to the very specialized ecophysiology of these animals.

# THE NMFS STRATEGIC PLAN FOR ALBACORE RESEARCH AND MANAGEMENT

by

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A joint Southwest Fisheries Center and Southwest Regional Office Task Force was formed to facilitate the strategic planning for NMFS' albacore research and management program. A probable scenario for the albacore fishery, based on the projection of current trends, was written by the task force. Constituents, informed by the scenario and other facts, chose objectives for the fishery and designated desirable future trends and events. Options for meeting the objectives were developed and classified into 10 design categories in an option field. NMFS management met to discuss the pros and cons of each option and to choose the set of options that represented the best strategy for NMFS to follow. As an example, three of the options that were selected are:

- expand international cooperative scientific studies on albacore,
- conduct R&D to improve forecasting and advisory system and
- establish a new international framework for management of the international and domestic north Pacific albacore fisheries.

# INTER-SPECIFIC RELATIONSHIPS BETWEEN EASTERN TROPICAL PACIFIC TUNAS AND THEIR PREY; IMPLICATIONS FOR FUTURE RESEARCH

by

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An understanding of the biotic interactions underlying fish production is desirable for managing fisheries resources. Our knowledge of trophic relationships in the eastern tropical Pacific Ocean (ETP) is limited to the uppermost and lowermost trophic levels. An important void in our knowledge is the competition and predator-prey relationships between the fish and cephalopod populations (the intermediate trophic levels) and their food base. These abundant animals undoubtedly have a great impact on the ecosystem in terms of both providing forage for the large predators (e.g. the tunas) and foraging at lower trophic levels.

The purpose of this presentation is to review the current knowledge of yellowfin and skipjack tunas' position in the ETP ecosystem. Food habits of yellowfin tuna are shown for inshore versus offshore areas, and the food habits of skipjack tuna are summarized for inshore areas. Frigate and bullet tunas (Auxis sp.) are the dominant food of yellowfin tuna in offshore areas and Pleuroncodes planipes, scombrids, portunid crabs, and cephalopods are important in inshore areas. Estimates of prey consumption by the CYRA (Commission Yellowfin Regulatory Area) yellowfin population are high (e.g. an average of >1.8 million metric tons of Auxis sp are eaten per year) based on laboratory measurements of gastric evacuation rates in conjunction with stomach contents data, and confirmed by bioenergetics studies and Cs/K ratios. Cephalopod remains occurred in 60% of the 3,662 yellowfin stomachs examined in the offshore areas, but their volume was low, due perhaps to

accumulation of squid beaks over time in the gut and feeding at night and digesting the squid prior to being caught in the day. Judging from the presence of numerous euphausiids in the stomach samples, skipjack tuna appear to feed at lower trophic levels than yellowfin tuna. The food habits of Auxis sp. in the ETP are not known, but it is conceivable that this important prey of yellowfin tuna may compete with skipjack tuna for euphausiids and other food.

Cs/K and $^{13}C/^{12}C$/ratios in the tissues of silky sharks, yellowfin tuna, skipjack tuna, frigate tuna, ommastrephid squids, flyingfish, and zooplankton in the ETP correlate well with trophic position assumed from stomach contents. These indicators provide a means of analyzing trophic structuring in the ETP. A potential application of these techniques with fisheries management implications would be to compare the Cs/K ratios, for example, of small tunas at various stages of development from larvae to recruitment size with those of other abundant animals in the ecosystem to identify competitors. It is anticipated that some of the organisms eaten by adult tunas may compete for food with larval or juvenile tunas at some stage in their development.

Five major groups of animals in the ETP ecosystem are identified as the most urgent and accessible for sampling of stomach contents. Sharks, dolphins, and yellowfin tuna can be sampled from associated schools aboard purse seiners. Auxis sp. occur incidentally in the tuna purse-seine catch, and epipelagic squids can be sampled at night from purse seiners and/or sampled from the catch of squid fisheries in the ETP.

Arguments are provided to support the notion that feeding selectivity of tunas is low within visual and morphological limitations, and that monitoring yellowfin stomachs sampled fishery-wide would provide better relative measures of micronekton abundance than do nets.

# RECENT DEVELOPMENTS AND FUTURE RESEARCH IN THE ATLANTIC OCEAN

by

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The International Commission for the Conservation of Atlantic Tunas (ICCAT) was founded in 1969, and has the responsibility of managing all tuna and tuna-like fishes in the entire Atlantic and adjacent seas. Unlike the Inter-American Tropical Tuna Commission (IATTC), data collection and population analyses are all done through the collaboration of national scientists. Some of the major fleets for which data have not been collected by any of the flag countries are covered directly by the Secretariat.

All the Atlantic tuna data are sent to the ICCAT Headquarters by the national laboratories and statistical offices, or collected directly by part-time ICCAT employees at ports. These data are entered into the ICCAT common data base and are available to any interested scientist, as long as the data do not violate the privacy of industry. They are also available in published form. The benefit of such an open system is obvious in that any scientist can present analyses based on a common data base at ICCAT scientific meetings for mutual review.

The ICCAT has minimum size regulations (3.2 kg) in force for yellowfin and bigeye, and (6.4 kg) for bluefin tunas, as well as a catch (or effort) regulation for bluefin tuna.

Intensive, cooperative research for skipjack tuna (International Skipjack Year Program) was completed in 1983. Based on the data obtained during this Program on tropical tunas, ICCAT scientists are now studying the small tuna

problems, i.e. small yellowfin and bigeye are caught together with skipjack in the Gulf of Guinea. The problem is whether the present minimum size regulations for these species are valid or can be implemented, or if there are any other alternatives to the regulations which would eliminate the taking of small tunas, yet have minimum effect on the skipjack fishery. The problem is being studied from a multi-gear, multi-species aspect.

# WIND AND ALBACORE CATCH 1970-1977

by

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A latitude-time plot of percentages of wind speeds less than 15 knots at selected coastal latitudes from 30°N to 49°N showed a similar pattern between times and locations of albacore catch and times and locations of low (<15 kts) wind speeds. In May or June the incidence of low wind speeds increased throughout most of the near-coast area involved in the albacore fishery. The coastal fishery began in May and June, coincident with moderating winds. Lower windspeed percentages covered broader times and space in southern latitudes and progressed northward as the season developed, until by August to October almost all latitudes showed low windspeeds. A similar pattern was evident in catch distribution. In October or November windspeeds increased in the north and progressed southward with time. Similarly, the pattern of catch declined.

This study was a preliminary exploration of the relationship between catch and windspeed. A more rigourous treatment of the data may be done at a future time.

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